Crustal and Paleo-Oceanographic Change of the Circum-Japan Sea area : A Review

著者	Arai Shoji
journal or publication title	Proceedings, International Symposium of the Kanazawa University 22st-Century COE Program
volume	1
page range	37-41
year	2003-03-16
URL	http://hdl.handle.net/2297/6360

Proceedings: International Symposium of the Kanazawa University 21st-Century COE Program Vol. 1 (2003)
Edited by Naoto KAMATA

Crustal and Paleo-Oceanographic Change of the Circum-Japan Sea area

A Review

Shoji ARAI
Department of Earth Sciences, Kanazawa University, Kanazawa, Ishikawa 920-1192, JAPAN

Abstract- The Sea of Japan (or East Sea) is one of typical backarc basins, unevenly distributed on the earth and concentrated in the Western Pacific. The backarc basins and surrounding areas of the Western Pacific, including the Circum-Japan-Sea area, are densely populated, and geological and tectonic impact on environments of inhabitants has been great. The Sea of Japan was abruptly formed by splitting of the eastern margin of the Eurasian continent either by forcibly or by passively. Its size and environment have changed in response with the tectonic and global environmental events. We are planning to research the Circum-Japan-Sea area in an inter-disciplinary way, i.e. by geological, tectonical, palaeoenvironmental and petrological methods. The wide expertises of the members of "Crustal and Paleo-oceanographic Change" group will enable to provide an integrated model for the environmental setting preparation for inhabitants on the backarc basin and surrounding area (= the Circum-Japan-Sea area).

I. Introduction

The Sea of Japan (or East Sea) is one of the back-arc basins between island arc and continent. It has been well known that almost all (about 75 %) back-arc basins on the earth are now present in the western part of the Pacific Ocean (e.g., [1]) (Fig. 1). The western part of the Pacific Ocean, including many trench-arc-back-arc basin systems, is densely populated, and we have numerous geo-environmental problems there due to natural and artificial causes. To start considering the problems we should understand geological or tectonic control on them as the base of human activities. The Circum-Japan-Sea area is one of the best loci on the earth to consider that geological or tectonic control on our environment because many lines of information on both natural and social scientific aspects have been accumulated to date. What kind of internal cause has made back-arc basins especially around the Western Pacific area? How have the Japanese islands and associated back-arc basin (the Sea of Japan) been formed?

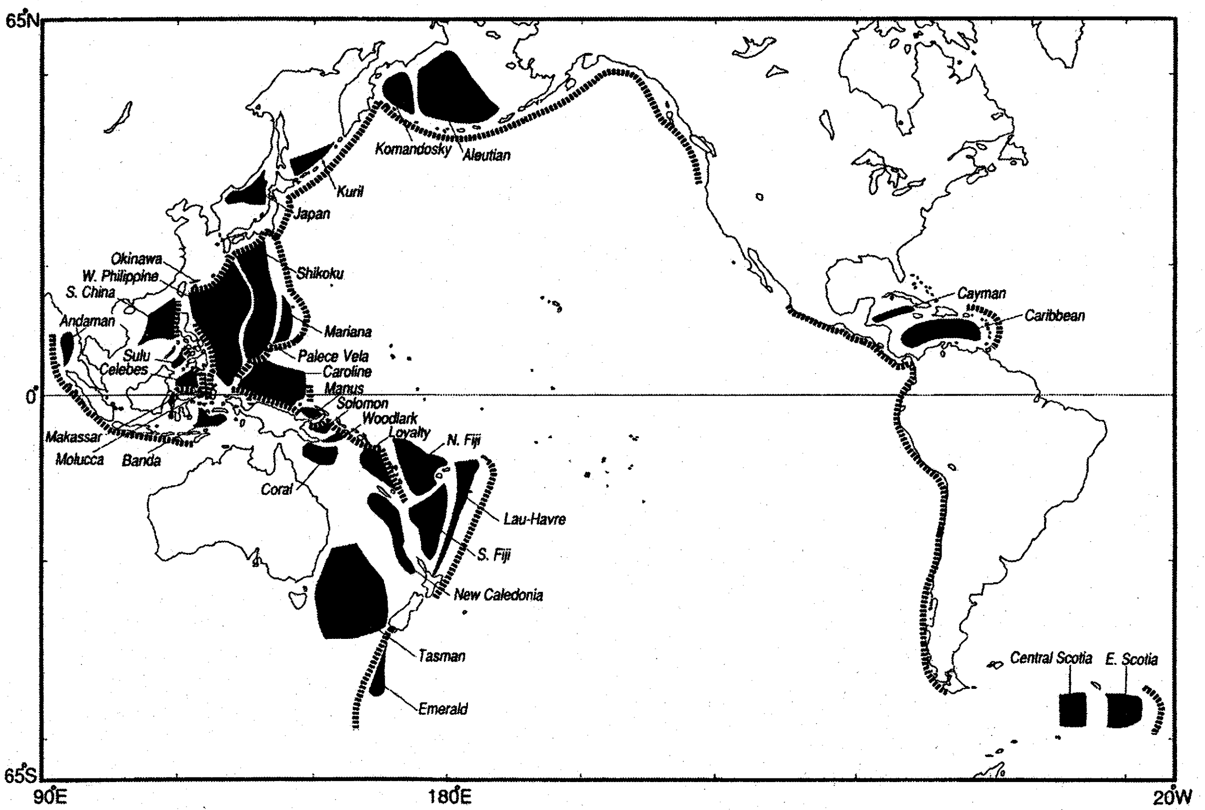

Fig. 1. Distribution of backarc basins. Black areas are backarc basins and thick broken lines are trenches. After [1].

II. Geological and Tectonic Background of the Sea of Japan as a Backarc Basin

Main characteristics of backarc basins can be summarized as follows [1]:

(1) Up to 75 % of all backarc basins on the earth are now concentrated in the Western Pacific, and the rest are in the western Atlantic (Caribbean and Scotia). In other words, they are distributed in the eastern margin of main continents where subduction is prominent. Note that backarc basins are absent at the western margin of South America where vigorous subduction has occurred.

(2) The lives of backarc basins are very short, about 25 m.y. on average, as compared with the ordinary major oceans. The formation of backarc basins is also intermittent within an area.

(3) Some backarc basins are destroyed by subduction afterstopping of spreading. For example, the Sea of Japan has initiated subduction on the western side of the Honshu Island [2].

(4) Although the 180 m.y activity of super-subduction in the Western Pacific, no backarc basins older than 80 Ma have not been preserved now.

(5) Some backarc basins apparently deeper (by 600 to 800 m) depths than the ordinary major oceans.

(6) Backarc basins sometimes change the spreading trend.

Miyashiro [3] proposed a hypothesis of "hot region" tectonics that requires opening of back-arc basins, including the Sea of Japan, in the Western Pacific by a migrating large mantle plume from deeper parts (Fig. 2). According to Miyashiro [3] a hot region passed through the Southwest Japan arc at 20 to 30 Ma. The idea of forcible opening of the Sea of Japan by asthenospheric injection was more recently supported on geochemical grounds by Tatsumi and coworkers (e.g., [4]).

Iwamori [5] and Uto [6] concluded that the asthenospheric mantle diapirism which resulted in the opening of the Japan Sea was responsible for the Cenozoic volcanism including eruption of the xenolith-bearing alkali basalts on the Southwest Japan arc. The magmatism of xenolith-bearing alkali basalts, which is young (11 to 1 Ma) relative to the age of Japan-Sea opening (around 15 Ma), may be a surface manifestation of a waning stage of the asthenospheric upwelling [5]. Okamura et al. [7] also concluded a forcible opening of the Sea of Japan: a mantle plume from deep mantle had moved from northeast China to the rim of the Eurasian continent (present Japan arcs).

Tamaki and Honza [1] summarized the tectonic models ever proposed for the backarc basin formation. They preferred a passive opening model, with a trench retreat toward the ocean (Fig. 2). In the passive opening model assumes dynamic asthenospheric flow beneath the subduction zone. A constant eastward asthenospheric flow due to earth's rotation accomplishes the trench retreat [8]. Alternatively a fluctuation of downgoing asthenospheric flow by which subduction is proceeding can be a cause of trench retreat. The passive opening model is consistent with the intermittent spreading and disruption of backarc basins or with the uneven distribution of backarc basins (Fig. 1) [1].

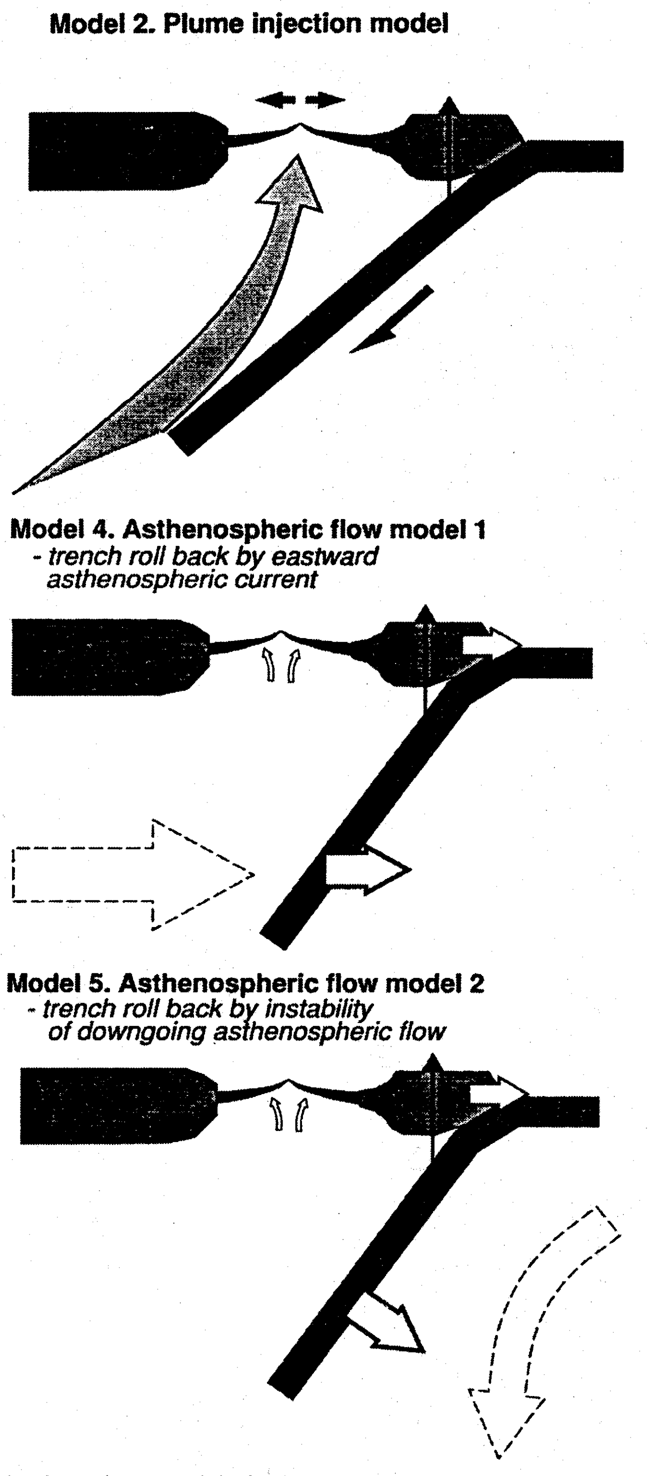

Fig. 2. Three models for backarc basin opening [1]. Model 2 is a model for forcible opening due to injection of hot plume from the deeper part [3]. Model 4 is a passive opening model due to trench roll back by eastward asthenospheric current [8]. Model 5 is also a passive opening model due to trench roll back by unstable downgoing asthenospheric current [1].

III. Tectonic Framework of the Circum-Japan-Sea area

One of the most prominent geological features of the Circum-Japan-Sea area is the development of sinistral strike-slip fault systems mainly of Cretaceous (Fig. 3). The regional strike-slip tectonics of the Cretaceous were so intense as to have large horizontal displacement up to several hundreds kilometers for some faults [9, 10] Small peridotite (or serpentinite) masses were uplifted from the upper mantle and were emplaced in the crust possibly through the strike-slip faults. On the Japan arcs detrital chromian spinels are commonly found in the Jurassic to Cretaceous sediments, suggesting serpentinite exposure was prominent at the period (Fig. 4).

Oblique convergence of plate frequently forms vertical strike-slip faults on the island-arc lithosphere above the subducting slab [e.g. 11,12]. The transcurrent movement is expected at the volcanic front to fore-arc region [e.g., 11]. Deformation of the island-arc lithosphere is prominent along the strike-slip faults [12].

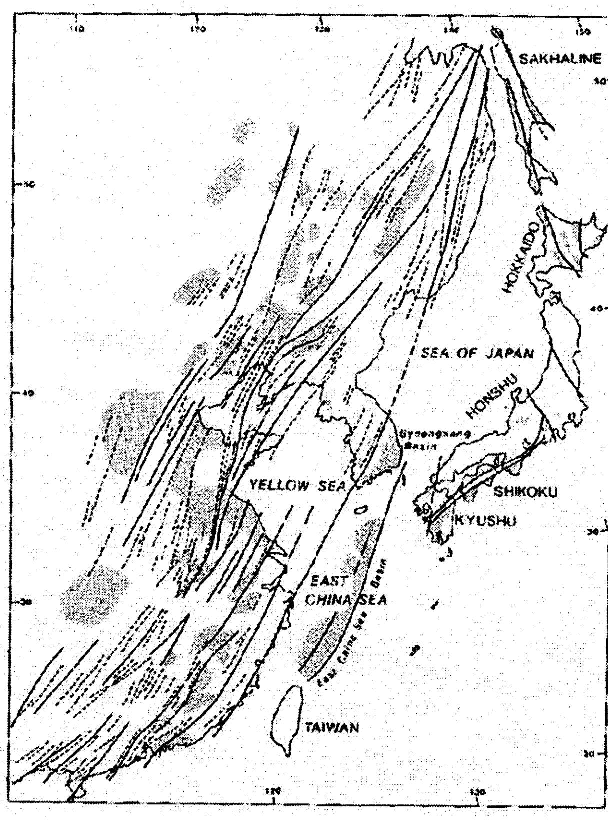

Fig. 3. Sinistral strike-slip fault systems in the Circum-Japan-Sea area [10].

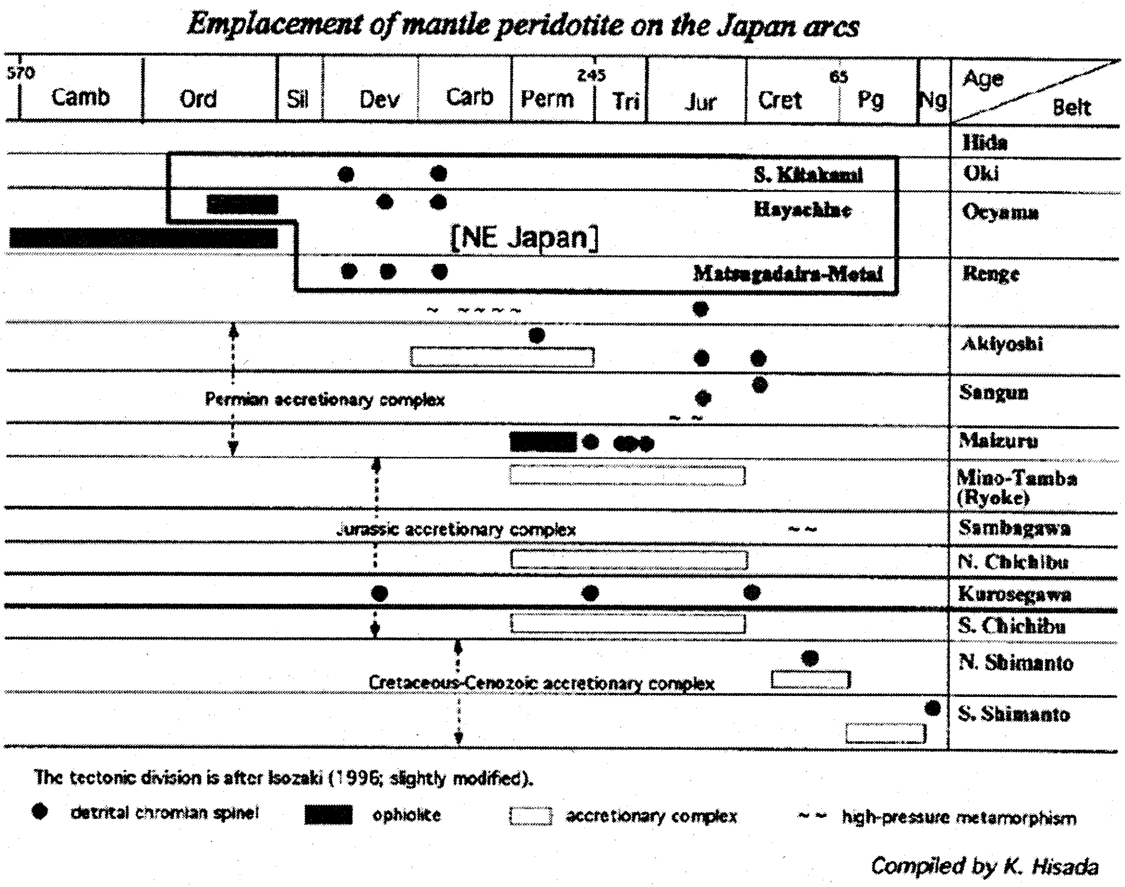

Fig. 4. Temporal and spatial relationships of serpentinite emplacement and occurrence of detrital chromian spinels in sediments on the Japan arcs. Compiled by K. Hisada.

IV. Upper Mantle Rocks Beneath the Circum-Japan-Sea Region: Modification by Japan-Sea Opening

The Cenozoic basalts that carry mantle-derived peridotite xenoliths are available from the Japan-Sea side of the Japan arcs except for the Shingu on the Shikoku Island [e.g., 13]. They can provide us therefore information on deep-seated rocks beneath the Japan Sea and surrounding area. The Southwest Japan arc is especially good place for examining the deep-seated rocks systematically by xenoliths because there are abundant xenolith localities. The lithospheric upper mantle is represented by lherzolite and harzburgite [e.g., 13, 14].

The lithospheric mantle was modified extensively through the geologic process related with the Japan-Sea opening. The lithospheric mantle was possibly made extensional by the upwelling asthenospheric mantle that had formed the Japan Sea basin and was then diked by alkali basaltic melts to accumulate Group II rocks. The melts were relatively hard to erupt but were possibly easy to accumulate in the deep parts in the early stage of the asthenospheric upwelling because of the still relatively weak extensional environment. The accumulation of large amounts of Fe-rich rocks and consequent intense metasomatism by intra-plate alkali basaltic melts are, therefore, characteristic of the upper mantle peridotites beneath the island arc with a back-arc basin like the Southwest Japan arc.

V. Future Research of the Group of "Crustal and Paleo-oceanographic change Crustal and Paleo-oceanographic change"

Backarc basins also provide the loci of deposition of sediments [e.g., 15]. *S. Tsukawaki* will examine in detail geological and recent sediments both on the Sea of Japan and on the Circum-Japan-Sea on-land area. His analysis of sedimentation therefore will give us a clue to the formation and development of the Japan Sea. The Sea of Japan had changed its size, depth and other environments from time to time, and this had been a strong impact on animals and plants in the water. *M. Kato* will collect the modern benthonic foraminifers from the Sea of Japan and will make detailed synecological analysis of the foraminfers. He will ultimately reconstruct the paleo-environmental change of the Circum-Japan-Sea area to compare with the fossil foraminfers from on-land Cenozoic sediments. *T. Kamiya* will examine evolutional and paleo-environmental aspects of ostracods, in respect of crustal and paleo-oceanographical change of the Sea of Japan. *C. Yatomi* will research mechanical characteristics of the over-riding plate, where the backarc basin, the Sea of Japan, had been formed. He will try to find out the condition of strike-slip formation by oblique subduction. The backarc basin was more easily open along such large fault systems. *S. Arai* and co-workers (*A. Ishiwatari, T. Morishita, K. Hisada and Y.I. Lee*) will try to clarify the primary characteristics and derivations of serpentinite (or peridotite) that have been emplaced on the Circum-Japan-Sea area (Japan, Korea and Far East Russia). *S. Arai and T. Morishita* also have a plan to study deep-seated xenoliths caught by volcanics on the Sea of Japan, namely from Cheju-do island, Oki-Dogo island and Oshima-Oshima island, as an insight into deep-seated processes beneath the Sea of Japan.

Acknowledgements

I wish express my deepest thanks to Professor K. Hayakawa, the leader of our 21st COE project, for his effort to arrange and lead the project, and to the other members of our COE project. I would especially indebted to my colleagues of our section, Dr. T. Kamiya, Prof. M. Kato, Dr. S. Tsukawaki and Prof. C. Yatomi, for their collaboration. Assistance of Dr. T. Morishita and Dr. M. Shirasaka in installation of La-ICP-MS is greatly appreciated. Collaboration with Prof. Y. I. Lee, Prof. D.C. Kim, Dr. A. Ishiwatari and Dr. K. Hisada about geological problems of Japan and Korea is greatly helpful for me.

References

[1] K. Tamaki, E. Honza, "Global tectonics and formation of marginal basins: Role of the western Pacific," *Episodes* Vol.14, 224-230, 1991.

[2] K. Tamaki, E. Honza, "Incipient subduction and obduction along the eastern margin of the Japan Sea," *Tectonophysics* Vol. 119, 381-406.

[3] A. Miyashiro, "Hot regions and the origin of marginal basins in the western Pacific," *Tectonophysics* Vol. 122, 195-216.

[4] Y. Tatsumi,, S. Maruyama, S. Nohda, "Mechanism of backarc opening in the Japan Sea: role of asthenospheric injection," *Tectonophysics* Vol. 181, 299-306, 1990.

[5] H. Iwamori, "Zonal structure of Cenozoic basalts related to mantle upwelling in southwest Japan," *Journal of Geophysical Research* Vol. 96, 6157-6170, 1991.

[6] K. Uto, "*Neogene Volcanism of Southwest Japan: Its Time and Space on K-Ar Dating*," Ph.D. thesis, University of Tokyo, 184p, 1990.

[7] S. Okamura, R.J. Arculus, Y.A. Martynov, H. Kagami, T. Yoshida, Y. Kawano, "Multiple magma sources involved in marginal-sea formation: Pb, Sr, and Nd isotopic evidence from the Japan Sea region," *Geology* Vol. 26, 619-622, 1998.

[8] S. Uyeda, H. Kanamori, "Back-arc opening and the mode of subduction," *Journal of Geophysical Research* Vol. 84, 1049-1062, 1979.

[9] J. Xu, W. Tong, G. Zhu, S. Lin, G. Ma, "An outline of the pre-Jurassic tectonic framework in east Asia," *Journal of Southeast Asian Earth Sciences* Vol. 3, 29-45, 1989.

[10] D.-W. Lee, "Strike-slip fault tectonics and basin formation during the Cretaceous in the Korean Peninsula," *The Island Arc* Vol. 8, 218-231, 1999.

[11] T.J. Fitch, "Plate convergence, transcurrent faults, and internal deformation adjacent to Southeast Asia and the Western Pacific," *Journal of Geophysical Research* Vol. 77, 4432-4460, 1972

[12] N. Pinet, P.R. Cobbold, "Experimental insights into the partitioning of motion within zones of oblique subduction," *Tectonophysics* Vol. 206, 371-388, 1992.

[13] S. Arai, H. Hirai, K. Uto, "Mantle peridotite xenoliths from the

Southwest Japan arc: a model for the sub-arc upper mantle structure and composition of the Western Pacific rim," *Journal of Mineralogical and Petrological Sciences* Vol. 95, 9-23, 2000.
[14] S. Arai, H. Hirai, N. Abe, "Petrological characteristics of the sub-arc mantle: An overview on petrology of peridotite xenoliths from the Japan arc," *Trends in Mineral* (India), Vol. 2, 39-55, 1998.
[15] H. Okada, T. Sakai, "Nature and development of Late Mesozoic and Early Cretaceous sedimentary basins in southwest Japan," *Palaeogeography, Palaeoclimatology, Palaeoecology* Vol. 105, 3-16, 1993.